time than mammals or frogs, and the difference is so striking that one must attribute it to the absence of medulla in Teleosts, and must assume that *the cortical gland is not absolutely essential to the life of the animal.* The longest time that a frog will survive removal of its capsules is, according to Abelous and Langlois,* twelve or thirteen days, and this period is shortened in the summer to forty-eight hours. Mammals usually die in a day or two.

The validity of these experiments depends obviously upon the fact that all suprarenal material has been actually removed at the operation. This has been verified in two ways. In the first place, previous study of the anatomy of the organs in many individuals has shown that the suprarenals are never more than two in number. Secondly, all three animals have been carefully dissected *post mortem*, and no trace of suprarenal bodies has been found to be left behind.†

Pettit‡ has described a true physiological compensatory hypertrophy of one suprarenal in the eel after the other one has been removed. This indicates a secreting function for this cortical gland. Pettit looks upon this organ in the eel as the fundamental type of the suprarenal capsule; but this view is quite untenable in the face of the facts that it has none of the characters of the double suprarenal of mammals, and its removal does not cause death.

"The Kelvin Quadrant Electrometer as a Wattmeter and Voltmeter." By Ernest Wilson. Communicated by Dr. J. Hopkinson, F.R.S. Received January 11,—Read January 27, 1898.

During the past seven years the author has had continued experience with the Kelvin quadrant electrometer, both in connection with scientific research and the training of electrical engineering students in the Siemens Laboratory, King's College, London. This paper embodies a good deal of the experience which he has gained with the instrument, and he has been fortunate in that two of these instruments were available. The numbers of the instruments are 71 and 184. The writer was therefore able to test the one as a Wattmeter, using the other for the purpose of investigating the instantaneous rate at which work was being done by alternate currents. The instrument used as a Wattmeter (No. 184) is of comparatively

* *Loc. cit.*

† For the animal which lived 119 days this statement has been verified by Professor Schäfer.

‡ 'Recherches sur les Capsules Surrénales,' Thèse. Paris (Félix Alcan), 1896.

recent construction, and differs from the other principally in the omission of the guard tube in the immediate vicinity of the needle surrounding a portion of the needle axis, and the wire connecting the needle to the acid inside the jar. The induction plate employed in the old form is done away with, and the terminals are permanently fixed to the quadrants in this new instrument, otherwise, so far as the author can see, they are identical. These instruments belong to Dr. J. Hopkinson, F.R.S., the old form being the same that he has used for many years, and in connexion with which he read a paper before the Physical Society on March 14, 1885.*

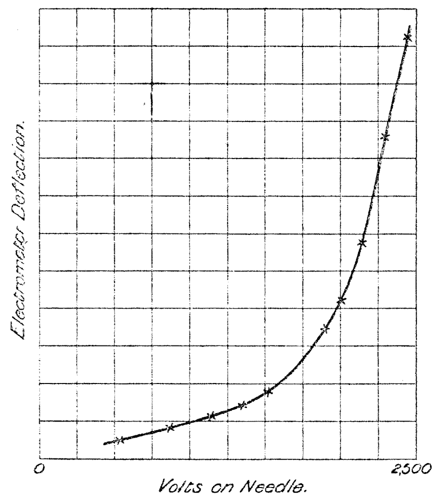
Verification of Clerk Maxwell's Formula.

In the paper just alluded to, it is shown that the sensibility of the instrument (No. 71) increased with the charge on the needle up to a certain point, and that for further increase of the charge on the needle the sensibility diminished. The complete explanation of this is not given, and the author believes Professors Ayrton and Perry were the first to point out that this effect is due to the portion of the guard tube in the immediate neighbourhood of the needle.

To test this point in the new instrument a Kelvin vertical electrostatic voltmeter was placed across the needle and case, and a constant electromotive force applied to the quadrants, one pair being put to the case. The jar was then charged by sparks from an electrophorus, and readings taken on the voltmeter and electrometer scale. The charge was continually increased until disruption occurred between the needle and the lantern which supports the idiostatic gauge. Up to about 2,450 volts on the needle the sensibility increased, and so far as the author could see the needle was further deflected as the charge was increased up to the point of disruption, the spot of light being then off the scale. No great care was taken with this experiment, since it was only carried out for the purpose of ascertaining if diminished sensibility could be obtained with further increased charge. The results are given in fig. 1. In Clerk Maxwell's 'Electricity and Magnetism,' vol. 1, p. 273, edition 1873, it is shown that the deflection of the needle of a quadrant electrometer should vary as $(A-B)\left(C-\frac{A+B}{2}\right)$, where C is the potential of the needle, and A and B the potentials of the two pairs of quadrants. In fig. 1 the E.M.F. between the quadrants was less than 1 volt, and was constant. By the formula the quotient C/θ should in this case be constant where θ is the observed deflection. It varies in arbitrary units from 0·55 to 0·11 as the value of C varies from about 550 to 2,450 volts. This is working the instrument far

* See 'Philosophical Magazine,' April, 1885.

FIG. 1.



beyond the range for which it is intended, since when the gauge is in proper adjustment the value of C is only about 550 volts.

In the following experiment the highest E.M.F. employed is 115 volts, and since a square root of mean square value equal to 100 volts was the maximum potential difference about to be used by the author in a certain series of experiments upon alternate current Watt-hour meters, it was necessary to see that within this range of potential the formula above given is verified. The instrument was connected as before with one pair of quadrants to the case, the other pair being insulated and the electromotive forces applied to the quadrants, as also to the needle, were supplied by storage cells, and accurately measured by Poggendorff's method, the standard of comparison being Clark's cell. The results are given in Table I.

The instrument in the above experiment was mounted on a slate base in the upstairs room of the Siemens Laboratory. The spot of light when working on this base with this instrument is never perfectly steady, and this may account for the errors observed in Table I.

Method of Test.

Fig. 2 gives a diagram of connections showing how the electrometer was used as a Wattmeter for alternate currents, and how it was tested when being so used. In the formula

$$\theta = \lambda(\mathrm{A}-\mathrm{B})\left(\mathrm{C}-\frac{\mathrm{A}+\mathrm{B}}{2}\right),$$

Table I.

Observed deflection θ.	A + B volts.	C volts.	$\dfrac{\left(C - \frac{A+B}{2}\right)(A+B)}{\theta}$.
+106	57·5	20·7	436
−140	58·6	39·5	427
−331	53·3	53·4	431
−552	52·7	71·6	432
−773	51·5	91·0	434
−551	32·5	89·7	433
−268	14·2	89·7	438
−352	14·1	115·0	432
−729	32·3	114·0	434
−726	48·5	88·9	432
−427	60·6	60·7	431
−338	88·9	60·7	427
−110	113 0	60·7	432
+626	113·0	32·2	439
+987	113·0	18·1	439
			433 mean

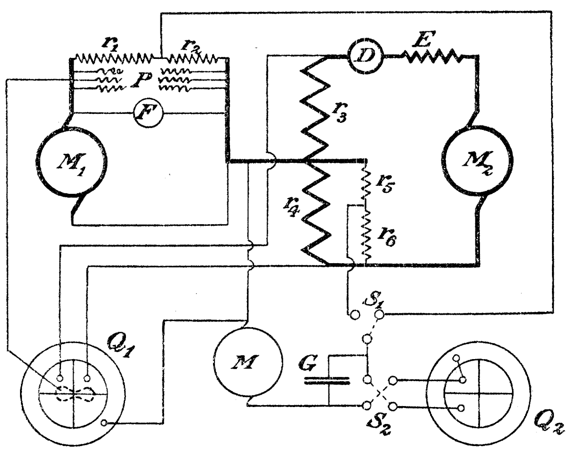


Fig. 2.

where λ is a constant, it follows that if A and B are in phase with one another and with the alternate current, and have the same wave form as the alternate current; and if C is in phase with the potential difference between two points of the circuit where the power is to be measured, and has the same wave form, A must be equal and opposite in sign to B, since the instantaneous rate at which work is done on or by the circuit must be proportional to AC or BC.

In the Siemens Laboratory there are two alternate current machines* coupled together in such manner that any desired phase difference between their armatures can be obtained. In fig. 2, M_1 and M_2 represent the armatures of these machines. On the shaft of one of these alternators is fixed a revolving contact maker, M, which makes contact between two brushes once in a period, that is six times in a revolution of the alternator, since there are twelve poles. It consists of a gunmetal disk keyed to the shaft of the alternator, and carrying two rings, one of ebonite and the other of gunmetal insulated from the disk by means of the ebonite ring. Into the ebonite ring are inserted six contact-making strips of gunmetal one-sixteenth of an inch thick, equally spaced out on the circumference and soldered into the gunmetal ring. An insulated copper brush bears on the gunmetal ring, and an insulated steel brush bears on the surface of the ebonite ring, touching each of the contact-making strips as the contact maker revolves. The epoch at which such contact is made by the small steel brush can be varied and observed by means of a pointer moving over a fixed circle divided into 360 equal parts. The diameter of this revolving contact maker is 13 inches.

Q_1 is the No. 184 electrometer used as a Wattmeter.

Q_2 is the No. 71 electrometer used in connection with the revolving contact maker M for the purpose of determining the instantaneous values of the current and potential difference.

D is a Kelvin balance or Siemens electro-dynamometer for the measurement of current; E is the thick wire circuit or circuits of the Watt-hour meters being tested; F is a Kelvin multicellular voltmeter; r_1, r_2 are non-inductive resistances of comparatively large value for the purpose of reducing the potential difference applied to the electrometer Q_2, when measuring potential difference C; the pressure circuits, P, of the Watt-hour meters are placed across r_1+r_2; r_3, r_4 are made up of a manganin strip 50·8 mm. wide and 0·4 mm. thick; $r_3 = r_4 = 0{\cdot}2275$ ohm at about 10° C.; r_5, r_6 are non-inductive resistances of considerable magnitude for reducing the potential difference applied to Q_2 when necessary. The junction between r_3 and r_4 is connected to the case of Q_1; the quadrants of this instrument are connected respectively to the extreme ends of r_3, r_4; whilst the needle of the electrometer is connected to the other pole of M_1. In connection with Q_2, S_1 is a two-way switch for observing potentials across r_2 or r_5; S_2 is the ordinary switch supplied with the electrometer which short-circuits the quadrants when moved to its central position, and in its two other positions reverses the charge on the quadrants; G is a condenser, which can be varied

* A full description of these machines is given in the 'Phil. Trans.,' A, vol. 187 (1896), p. 231.

from 0·001 to 1 microfarad, its capacity being 1 microfarad during the experiments, the results of which are given in Table II.

Before giving the results of the experiments it is well to explain the method adopted of treating the curves for the purpose of arriving at the average Watts due to the alternate current, the relation between which and the deflection of the electrometer used as a Wattmeter it is desired to find. It is also necessary to examine the limits of accuracy obtainable by this method. In any one experiment the frequency employed is kept constant as nearly as possible: the phase difference between current and potential is adjusted to any desired value and the amplitude of these quantities is kept constant by observing their square root of mean square values on the instruments D and F. The revolving contact maker M is then set to different positions of the phase, the number employed being at least ten equal divisions to the half period, and for each position, readings taken on the electrometer Q_2 when the switch S_1 is in each of its two positions. If the deflections so obtained be plotted in terms of the position of the revolving contact maker M, the forms of the two curves are those due to the instantaneous values of the potential difference applied to the needle of the electrometer Q_1, and the current which gives the form of potential difference applied to the quadrants of Q_1. By multiplying each of these deflections together, and by a suitable constant involving the square of the sensibility of Q_2 and the resistances r_1, r_2; r_3, or r_3; r_5, r_6, the instantaneous rate at which work is being done by the alternate current can be inferred in Watts. The average of these over a half period gives the average rate, and this can be obtained by plotting the instantaneous product and taking the area with a planimeter, or the average of the algebraic sum during a half period can be taken. The author found the latter method agreed so well with the former when the number of intervals at which observations are taken is ten, that he has adopted it in this paper, that is to say, the two electrometer deflections for a given position of M are multiplied together, the average of these taken over half a period, and such average multiplied by a constant to reduce to Watts.

The best way, perhaps, to test the limits of accuracy is to adjust current and potential until they are exactly in phase. The voltmeter F and amperemeter D give the square root of mean square values, and the product of these should agree with the average results obtained from the curves. The time required to take one set of observations is generally about twenty minutes, during this time an average for volts, amperes, and frequency is taken. The author finds from experience that if care be taken an agreement between the results got from the curves, and from the product of volts and amperes, can be obtained to within one or two per cent. It

must be remembered that for each position of the contact maker, *four* observations on the electrometer (Q_2) scale have to be obtained; that is, two for potential and two for current corresponding to the two positions of S_2 for each position of S_1, the difference in each case giving the net double deflection. This method is best, as it eliminates any zero error there may be. In working the electrometer Q_2, a wooden tapper or mallet is employed, since in every electrometer there must be viscosity due to the fluid, and by gently tapping the slate base for each deflection very consistent results can be obtained. This viscosity is greater in winter, and it is advisable to keep the instrument in a warm room, although with this method of tapping the author does not find this necessary. The greatest trouble in the use of the electrometer undoubtedly arises from dust settling on the surface of the acid in the jar, thereby making the angular movement of the wire hanging from the needle smaller than it would be if such brake action did not exist. This takes place when the acid in the jar is old, and if the surface be agitated by blowing through a glass tube near where the wire dips into the acid it can be to a great extent remedied. Whatever the state of the acid the author finds he gets the most consistent results by gentle tapping. The electrometer Q_1 is not so sensitive as the old form Q_2, and the effect due to the acid in it has not given so much trouble. The sensibility of Q_2 when the idiostatic gauge is adjusted is such that one Clark cell gives a deflection from zero of $10\frac{1}{2}$ inches on a scale 12 feet from the mirror. The potential of the needle is in this case about 350 volts.

Experimental Results.

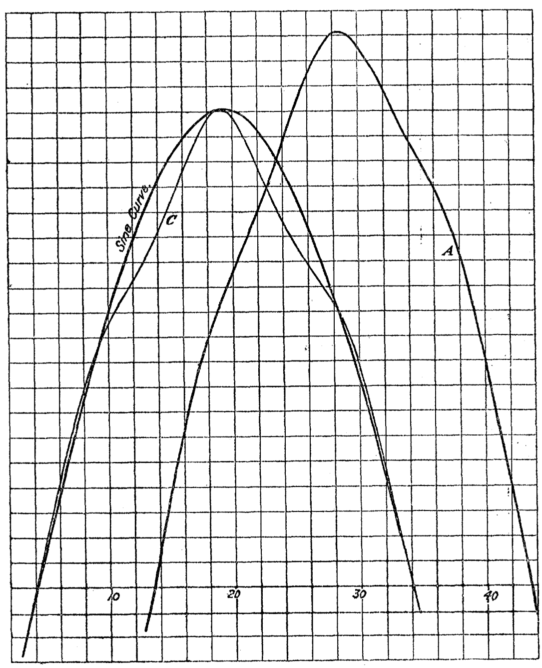
In making a thorough test of the electrometer as an alternate current Wattmeter we have the following variables to deal with :—

1. The frequency of the alternate current.
2. The phase difference between current and potential, that is between C and A or B.
3. The amplitude of C and A or B.
4. The shape or wave form of the curve of potential and current.

The results obtained are tabulated in Table II and are divided into three groups (*a*) (*b*) (*c*). In group (*a*) two frequencies are given, namely 41·6 and 83 complete periods per second. The potential on the needle is constant at about 100 volts ($\sqrt{\text{mean}^2}$). The phase difference between potential and current and the current itself are each varied. When the phase difference is zero, it is only necessary to take the product of the $\sqrt{\text{mean}^2}$ values to deduce the Watts, although in section (*b*) three instances are given in which for phase difference zero, the Watts are deduced by both methods. The

average Watts per division given by section (*a*) are 17·00 for all angles of phase leaving out the two values deduced by aid of the cosine law for angles of 30° and 60°. It will be seen that under the conditions of section (*a*) the Wattmeter may be said to be verified within the limits of accuracy attainable by the method of test. The wave form of the unloaded alternator is given in fig. 3 and marked C; this is the wave form of potential applied to the needle in all experiments in sections (*a*) and (*b*). A sine curve having the same maximum ordinate is superposed for the purpose of comparison. The current curve has different wave form according to the load on the alternator. For small currents it approximates to C in fig. 3. The curve A, fig. 3, is the wave form for current 74 amperes, which is the maximum we have employed.

FIG. 3.



The experiments in section (*b*), Table II, are intended to demonstrate the reliability of the instrument when the potential of the needle C is varied through wide limits. One would expect from the curve in fig. 1, that for high potentials on the needle the Watts, per division of the scale, would diminish. This is found to be the case when the potential C is raised to 1,860 volts ($\sqrt{\text{mean}^2}$) for fre-

Table II.

Frequency.	Phase difference in degrees. 360° = 1 period.	Potential of needle C in $\sqrt{\text{mean}^2}$ volts.	Current in amperes $\sqrt{\text{mean}^2}$.	Watts.		Watts per division of scale.		Date of experiment, 1897.
				From product of volts and amperes.	Given by curves.	From product of volts and amperes.	Given by curves.	
(a)								
41·6	0·0	100·35	39·65	3979·0	..	16·79	..	November 24
41·6	0·3	99·85	17·11	1709·0	..	16·75	..	,, ,,
41·6	0·0	100·4	39·8	3996·0	..	16·79	..	,, 25
41·6	29·7	100·3	39·85	3996·0	3371·0	..	16·85	,, 23
41·5	31·5	99·66	16·85	..	1457·0	..	17·30	,, ,,
41·6	30·0	100·0	39·6	..	..	17·23*	..	,, 25
41·6	59·4	100·0	39·7	..	..	18·54*	..	,, ,,
83·0	0·0	99·3	39·24	3897·0	..	16·87	..	,, 30
83·0	0·0	100·0	29·91	2991·0	..	16·85	..	December 1
83·0	0·0	101·7	9·64	980·6	..	16·90	..	,, ,,
83·0	0·0	101·5	9·70	984·5	..	17·27	..	,, 2
83·0	0·0	99·5	39·45	3925·0	..	16·85	..	,, ,,
83·0	0·0	101·0	73·98	7472·0	..	16·68	..	,, ,,
83·0	61·9	99·6	19·76	1968·0	892·3	..	17·5	,, 1
83·0	39·3	99·4	40·15	..	3191·0	..	17·34	,, ,,
83·0	63·9	100·0	39·9	..	1622·0	..	17·07	November 30
83·0	60·0	101·7	74·15	..	4097·0	..	17·29	December 4
(b)								
82·0	1·2	563·0	11·89	6689·0	6736·0	15·67	15·77	December 4

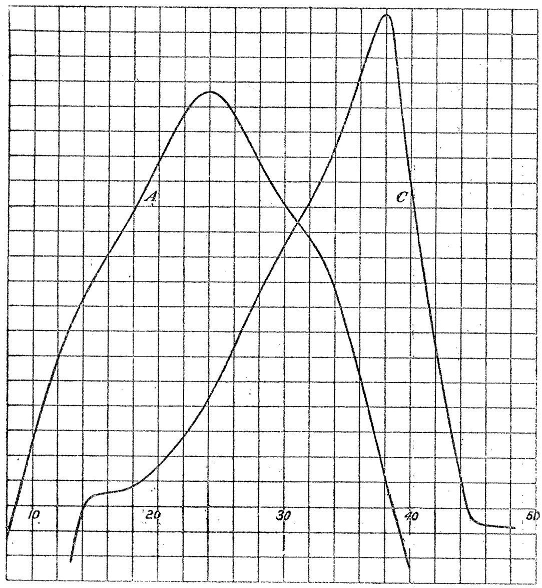
* Watts deduced by Cosine Law.

Table II—*continued.*

Frequency.	Phase difference in degrees. 360° = 1 period.	Potential of needle C in $\sqrt{\text{mean}^2}$ volts.	Current in amperes $\sqrt{\text{mean}^2}$.	Watts.		Watts per division of scale.		Date of experiment, 1897.
				From product of volts and amperes.	Given by curves.	From product of volts and amperes.	Given by curves.	
83·0	60·0	553·0	11·83	..	3142·0	..	15·25	December 4
83·2	0·8	630·0	10·86	6842·0	6892·0	16·25	16·37	" 11
83·0	65·4	623·0	10·3	..	2433·0	..	15 7	" "
75·0	0·0	1860·0	2·33	4330·0	..	10·93	..	" 18
75·0	0·0	1860·0	1·25	2320·0	..	11·40	..	" "
53·6	0·0	438·0	16·03	7020·0	7162·0	16·52	16·85	" 9
53·7	64·8	436·0	15·01	..	2868·0	..	16·49	" "
43·0	0·0	1840·0	2·39	4400·0	..	11·21	..	" 17
43·0	0·0	1840·0	1·30	2390·0	..	11·60	..	" "
(*c*)								
50·4	6·0	117·2	45·0	5275·0	5350·0	15·91	17·15	December 15
50·4	36·0	117·8	45·0	..	2741·0	..	16·82	" "

quencies of 75 and 43. In section (*c*) the wave form is very much distorted. The curves of potential and current are plotted in fig. 4.

FIG. 4.



The distortion of the potential curve C was brought about by placing a considerable non-inductive resistance in series with a choking coil, and taking potentials across the choking coil. The instrument under these conditions gives trustworthy results. The phase difference on one or two occasions was such that the curves indicated no work, the deflection under these conditions was zero. The maximum angle of deflection of the needle from its normal position was 7·8°, and tests were made from time to time, especially with the large potentials on the needle, to see if the instrument was in proper adjustment, by placing both pairs of quadrants in connection with the case, and noting the agreement between its then zero and the zero when quadrants and needle were put to the case, that is when the instrument was totally discharged. To test the effect of dismounting the instrument the needle was taken off the suspension and the instrument moved to another room and used for another purpose, on December 10, 1897. On continuing the experiments it was set up by the level only, and found to be in proper adjustment. The results of experiment before and after this removal are given in Table II.

Seeing from fig. 3 how great was the deviation from the sine law, it would have been necessary to analyse each curve by Fourier's theorem, if the subject was to have been treated mathematically, the phase difference being given. The current curve was continually changing its form with different loads, and this would have necessitated observing the curve in each case, so that nothing was to be gained by this method of treatment. The potential curve C, fig. 3, has, however, been analysed,* and can be expressed by the equation—

$$C = B_1 \sin \frac{2\pi t}{T} + B_3 \sin \frac{6\pi t}{T} + \ldots .$$

The first five co-efficients are as follows :—

B_1	B_3	B_5	B_7	B_9
540·1	1·9	31·5	−6·5	1·3

We see that B_5 is important, being about 6 per cent. of B_1; so that from the analysis the cosine law could not be expected to hold. In section (a), Table II, the cosine law is applied in two instances for the purpose of illustration. It gives 18·54 as against 17·0 for the Watts, per division of scale, for 60°; and 17·2 as against 17 for 30°. For small angles the error does not appear to be so great.

The conclusions arrived at from these experiments are that the Kelvin Quadrant Electrometer can be used with accuracy as a Wattmeter in the case of alternate currents having any phase relation, and that, as pointed out by Dr. J. Hopkinson,† it is necessary to see that within the range of potentials applied, Maxwell's formula is verified. This is, perhaps, best done by applying steady potential differences to the needle and quadrants, and measuring these by Poggendorff's method, employing Clark's standard cell as the unit of comparison. It could also be tested by applying known alternating potentials to the needle and quadrants, the curves being in phase. If it is required to use alternating potentials of high value, such, for instance, as 2000 volts or more, a suitable transformer could be employed to reduce the potential on the needle. Such unloaded transformer could have the primary and secondary electromotive forces in phase, and of the same wave form,‡ so that no error would be thereby introduced.

* 'Electrician,' August 31, 1894, p. 517.

† 'Philosophical Magazine,' April, 1885.

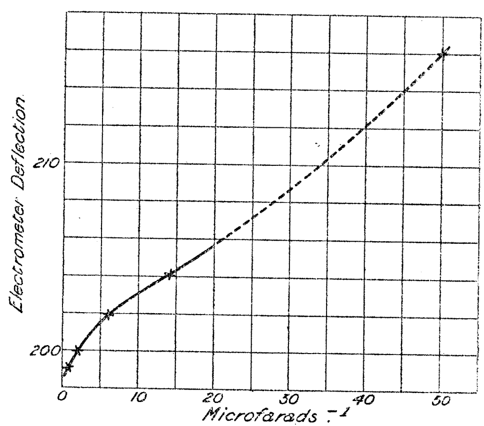
‡ 'Electrician,' February 15, 1895, p. 463.

The Revolving Contact Maker.

The revolving contact maker M, fig. 2, exhibits a peculiarity worth noting. It is in itself the seat of an electromotive force, as is demonstrated by placing it across the electrometer Q_2, and running the machines without excitation. A deflection of 68 scale divisions, corresponding to 0·45 volt, is given if the electrometer has no capacity across its terminals, that is, if G is zero. A copper brush gives the same effect as a steel one. As soon as G is given a substantial value as compared with the electrometer itself, this deflection disappears.

When actually observing potentials in the usual way, let the value of G be varied. For a given position of the contact maker the deflection varied, as shown in fig. 5, in which the ordinates are observed

Fig. 5.



deflections, and the abscissæ the reciprocals of the capacity of G in microfarads. We see that when G has 1 microfarad capacity, the deflection is practically what it would be if G were ∞, and with 1 microfarad the results verify with the true value. Such inductive effect is certainly rendered negligible by sufficient capacity, and it is therefore wise to examine this effect when working with a given contact maker, since each one may have its own peculiarities.

The Manganin Strip.

The manganin strip r_3, r_4, fig. 2, is in lengths of 5 feet, brazed together. This material has altered its resistance, as shown in Table III.

Table III.

Date.	Resistance at atmospheric temperature in ohms.
1st November, 1897	0·4625
3rd " "	0·4590
13th " "	0·4592
20th " "	0·4589
" " "	r_3 = 0·2269
" " "	r_4 = 0·2270
4th January, 1898	r_3 = 0·2275
" " "	r_4 = 0·2277

The strip was mounted on November 1, 1897, and submitted to currents varying from 100 amperes downwards. On November 20, 1897, it was adjusted for r_3, r_4. The results show that there is an initial diminution of resistance, and that then the resistance remains practically constant. This is worth noting, as this material is largely used at the present time, on account of its low temperature coefficient. The manganin strip is unvarnished and exposed to the atmosphere of the engine room. The conditions are therefore not the best to secure constancy of resistance, but in all probability the initial diminution is due to the brazing.

Messrs. C. J. Evans and H. H. Hodd have given me valuable assistance, not only in the experimental part of this paper, but also in the working out of the results. Messrs. Simpson, Greenbank, and Davey, the present Student Demonstrators in the Siemens Laboratory, have also helped me. I wish to acknowledge this, and to tender my thanks to these gentlemen.

"The Magnetic Properties of almost pure Iron." By ERNEST WILSON. Communicated by Dr. J. HOPKINSON, F.R.S.

Received January 11,—Read January 27, 1898.

One of the two rings of almost pure iron supplied by Colonel Dyer, of the Elswick Works, to Sir Frederick Abel, K.C.B., F.R.S., by whom they were sent to Dr. John Hopkinson, F.R.S., has already formed the subject of a communication,* and is herein referred to as Pure Iron I. As this pure iron has not been directly tested for dissipation of energy due to magnetic hysteresis, and the second ring was available, the author thought it would be interesting to examine

* 'Roy. Soc. Proc.,' vol. 52, p. 228.